DEPARTMENT OF THE ARMY
MOBILE DISTRICT, CORPS OF ENGINEERS
P. O. BOX 2288
MOBILE, ALABAMA 36628

REPLY TO
ATTENTION OF:
Environmental Quality Section

May 4, 1984

DACW01-79-C-0224

TO ALL INTERESTED PARTIES:

In November of 1980 we sent you a copy of the Engineering and Environmental Study of DDT Contamination of Huntsville Spring Branch, Indian Creek, and Adjacent Lands and Waters, Wheeler Reservoir, Alabama, prepared under contract by Water and Air Research, Inc. (W.A.R.) for the Mobile District.

In a detailed review of the report data in preparation for testimony in conjunction with a legal case, W.A.R. found that an error had been made in the calculation for the total number of tons of DDT in Huntsville Spring Branch (HSB) and Indian Creek (IC). According to Dr. James H. Sullivan, Project Manager for W.A.R., this error resulted from two causes: (1) a misinterpretation of the units for some of the data received from the Tennessee Valley Authority and (2) some wrong data being entered into the computer program that calculated the total DDT present. This error impacts all references to the total amount of DDT present at any particular location in the HSB-IC system. However, it has no impact on concentrations of DDT in sediments or on any of the impacts of DDT on fish or other species.

The main difference between the old and new figures is the total, 637 tons originally vs. 475 tons now. Another difference is that the new figures show that the majority of the DDT is in the channel, not the overbank. The relative amount of DDT in each stream reach has changed very slightly as follows:

Stream Reach	Old Data	New Data
Upstream of Dodd Rd. in HSB	95.9%	97.8%
Dodd Rd. to IC	3.1%	1.4%
Indian Creek	1.0%	0.8%

W.A.R. has considered the possible impact of these new figures on the clean-up alternatives proposed in 1980. Their conclusion is that there is no change. The most significant facts that led to the selection of these alternatives were: (1) that fish were highly contaminated in all parts of the HSB-IC system and even in the Tennessee River, (2) that a significant amount of the fish contamination appeared to be resulting *in situ* from very low sediment concentrations, and (3) that the concentrations of DDT in sediment in all parts of the HSB-IC system were well above that which would result in fish concentrations above 5 ppm. Hence, the alternatives that deal with clean-up of all contaminated parts of HSB-IC are still valid. This is not meant to imply that other alternatives could not be developed that might be appropriate, only that the error found in the original work does not impact the alternatives developed at that time.

In response to our request, W.A.R. prepared pages to be inserted in the report. These pages incorporate all changes resulting from correction of the sediment DDT calculation error as well as the errata sheets dated January 1981. The enclosed revision pages should replace all pages in the original document with corresponding page numbers.

We regret the error; however, we feel that it does not alter the basic conclusions of the 1980 report. If you have any questions about these revisions, please call Dr. Diane Findley at 205/694-3857 or FTS 537-3857.

Sincerely,

Willis E. Ruland
Chief, Environment and Resources
Branch

Enclosure

Each page has been stamped "REVISED April 1984" even though the revisions may exist only on one side.

EXECUTIVE SUMMARY

1.0 INTRODUCTION

This report deals with DDTR contamination in northeast Alabama in the Tennessee River system from Mile 260 to 375 which includes Wilson, Wheeler, and Guntersville Reservoirs. The primary area of interest is the Huntsville Spring Branch - Indian Creek (HSB-IC) tributary system which enters the Tennessee River (TR) at Mile 321. From 1947 to 1970 a privately operated DDT plant on Redstone Arsenal discharged waste containing DDT residues (DDT + DDD + DDE), commonly referred to as DDTR. A major impact of these residues has been the contamination of certain fish species to DDTR levels exceeding the 5 ppm limit set by the Food and Drug Administration (FDA) for edible portions of fish.

In the spring of 1979 an engineering and environmental study was initiated by the Department of the Army, with study management by the U.S. Army Corps of Engineers, to establish the basis for determining whether corrective action is required, and if so, the engineering approach to such corrective action. This contract report to the Corps defines the nature and extent of the contamination and evaluates the engineering, economic, and environmental feasibility of a broad range of alternative solutions. The study included extensive field and laboratory work performed largely by the Tennessee Valley Authority (TVA). Data were gathered on fish, sediment, water, macroinvertebrates, plankton, aquatic plants, mammals, birds, and reptiles in the area. Additionally, efforts were made to secure all prior existing data relevant to this subject.

One area specifically excluded from this study was human health effects. That aspect of the problem is being investigated by the Center for Disease Control in Atlanta.

2.0 EXTENT OF THE PROBLEM

Historically, wastes from the DDT manufacturing plant flowed down a ditch to HSB at about Mile 5.4. Records exist indicating contamination of sediments in HSB to levels exceeding 10,000 ppm as early as 1963. In 1970 analysis of fish from the area showed some samples from both Wilson and Wheeler Reservoirs exceeding the 5 ppm criteria. In the early 1950's, bird population estimates for Wheeler National Wildlife Refuge, which includes the contaminated area, showed declines of certain species. However, since many of the species were migratory, it cannot be definitely concluded that this contamination caused the decline.

In the late 1970's much more extensive information was gathered regarding the extent of contamination in sediments, water, plants, and animals. It is estimated that some 475 tons of DDTR currently exists in the sediments of HSB and IC. About 34 percent of the DDTR is in the top 6 inches of sediment. On an areal basis, about 97.8 percent of the DDTR is in HSB upstream of Dodd Road between Miles 2.4 and 5.4. Another 1.4 percent is in the lower 2.4 miles of HSB and the final 0.8 percent is in the lower 5 miles of IC. About 99.9 percent of the DDTR is in the bottom sediments with the remaining amount in the water, plants, and animals.

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DDTR is being slowly moved downstream through the HSB-IC system and out into the TR. Very low, but detectable quantities of DDTR exist in TR sediments downstream of IC.

Fish surveys made in 1979 and 1980 indicate that fish, particularly channel catfish, in the IC area have DDTR concentrations well above the 5 ppm level, many greater than 50 ppm. It appears that channel catfish are the most contaminated species and that they may have DDTR levels above 5 ppm in essentially all parts of Wheeler Reservoir. Smallmouth buffalo are contaminated to a lesser degree but at some locations had greater than 5 ppm DDTR. Largemouth bass generally had less than 5 ppm DDT although some individual fish had concentrations greater than 10 ppm. White crappie, white bass, and bluegill generally appear to have levels less than 5 ppm but may exceed limits in the IC area.

Two factors seem to be causing high levels of DDTR in catfish and smallmouth buffalo in the TR. First, the level of DDTR in the TR downstream of IC, although low, is sufficient to cause an elevated base level of contamination. In channel catfish this base appears to be near the 5 ppm criteria. Second, migration of fish from the more contaminated area of IC results in high concentrations at other sites above what would be produced by local contamination.

Elevated levels of DDTR have been found in birds and other animals in the area and particularly in those living near HSB and IC.

In summary it appears that:

1) an extensive amount of DDTR is in the sediments of HSB and IC

2) this DDTR is being slowly moved through the HSB-IC system and out into the TR

3) fish, particularly channel catfish, are highly contaminated with DDTR in IC and throughout Wheeler Reservoir they have DDTR levels above the 5 ppm criteria

4) contamination of fish in the TR results from low levels of DDTR that now exist in the water and/or sediment downstream of IC

5) contamination of fish in the TR also appears to be caused by the migration of contaminated fish to areas relatively uncontaminated.

3.0 ALTERNATIVES FOR MITIGATION OF THE PROBLEM

A full range of alternatives for mitigation of this problem was investigated. All can be compared with the Natural Restoration Alternative which is to allow the situation to be cleaned up by natural processes. Unfortunately, it appears that this alternative has little or no chance of significantly improving the situation in any reasonable time period.

Table 2 . Estimated Level of Mitigation, Predicted Impacts, and Estimated Costs Associated With Proposed Alternatives.

Alternative	Estimated % DDTR			Predicted Adverse Environmental Impacts	Est. Cost millions
	Remove	Cover	Total		
A	0	0	0	(1) DDTR continues to move down HSB to IC and the TR (2) Fish and other biota continue to have elevated DDTR levels	0.6/yr
B	99.4	0	99.4	(1) Significantly alter 313 acres wetland, 228 acres aquatic habitat (2) Lose "edge" habitat along dredged stream (3) Lose Aufwuch communities and snag habitats in dredged stream (4) Some short-term water quality loss	86.6
C	99.4	0	99.4	(1) Significantly alter 684 acres wetland, 495 acres upland, and 313 acres aquatic habitat (2) Dredging impacts (2)-(4) listed under Alternative B (3) Increase in suspended solids and nutrients loading to the TR via the diversion channel	137
D	1.9	97.5	99.4	(1) Significantly alter 701 acres wetland, 521 acres upland, and 313 acres aquatic habitat (2) Dredging impacts (2)-(4) listed under Alternative B for dredging downstream from Dodd Road (3) Increase in suspended solids and nutrient loading to the TR via the diversion channel (4) Drier habitat in HSB between Patton and Dodd Roads	130

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Table 2. Estimated Level of Mitigation, Predicted Impacts, and Estimated Costs Associated With Proposed Alternatives. (Continued)

Alternative	Estimated % DDTR			Predicted Adverse Environmental Impacts	Est. Cost millions
	Remove	Cover	Total		
E	99.4	0	99.4	(1) Significantly alter 619 acres wetland, 348 acres upland, and 338 acres aquatic habitat (2) Dredging impacts (2)-(4) listed under Alternative B for dredging downstream from HSB Mile 3.9 (3) Increase in suspended solids and nutrient loading to IC via the diversion channel	105
F	13.2	86.2	99.4	(1) Significantly alter 612 acres wetland, 348 acres upland, and 338 acres aquatic habitat (2) Dredging impacts (2)-(4) listed under Alternative B for dredging downstream from HSB Mile 3.9 (3) Increase in suspended solids, nutrient loading to IC via the diversion channel (4) Drier habitat in HSB between Miles 3.9 and 5.6	94
F*	13.2	86.5	99.7	(1) Significantly alter 612 acres wetland, 161 acres upland, and 338 acres aquatic habitat (2) Dredging impacts (2)-(4) listed under Alternative B for dredging downstream from HSB Mile 3.9 (3) Increase in suspended solids and nutrient loading to IC via the diversion channel (4) Drier habitat in HSB between Miles 3.9 and 5.6	88

* Alternative F with option to use diked contaminated area for disposal of dredged material.

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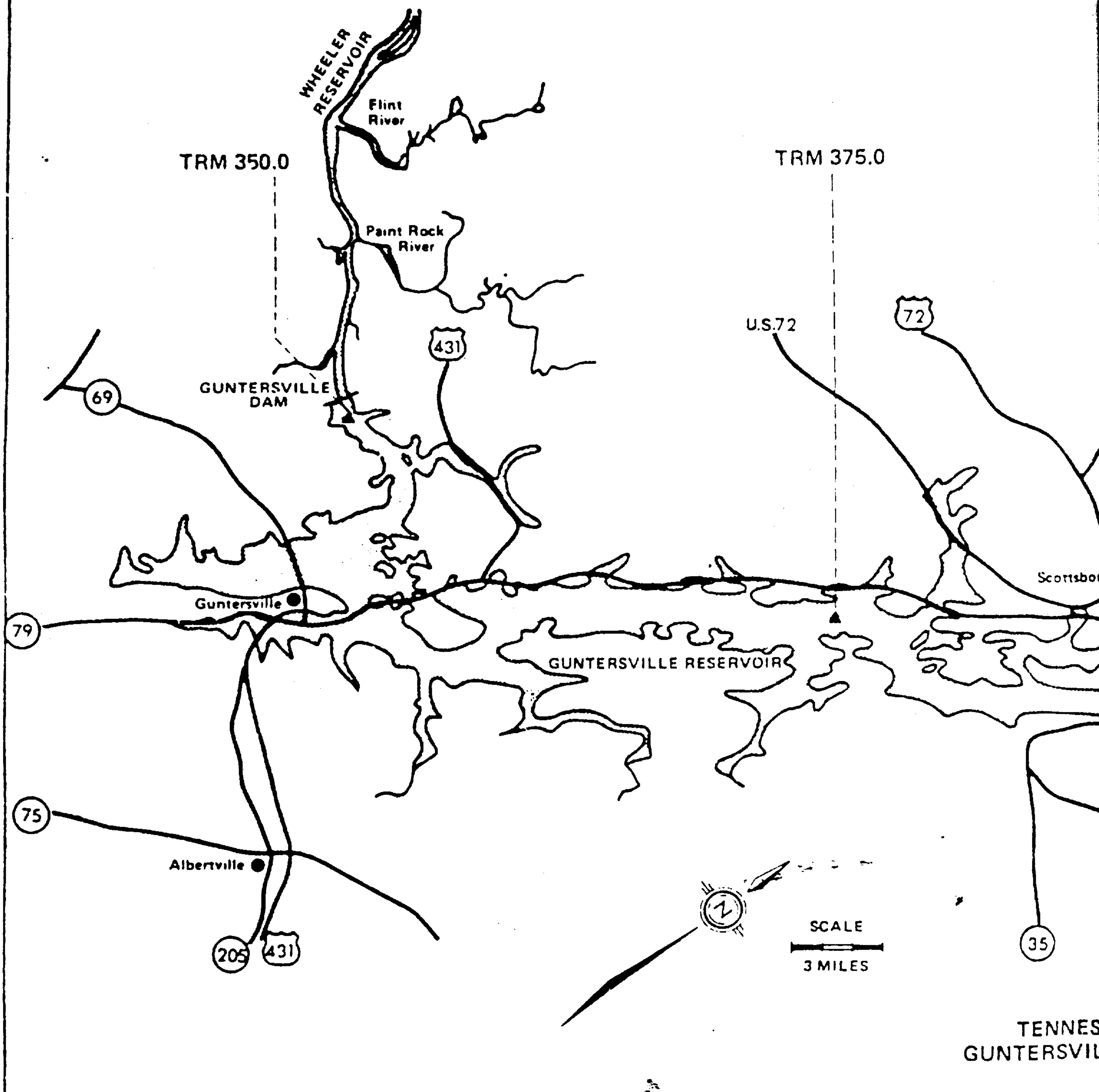
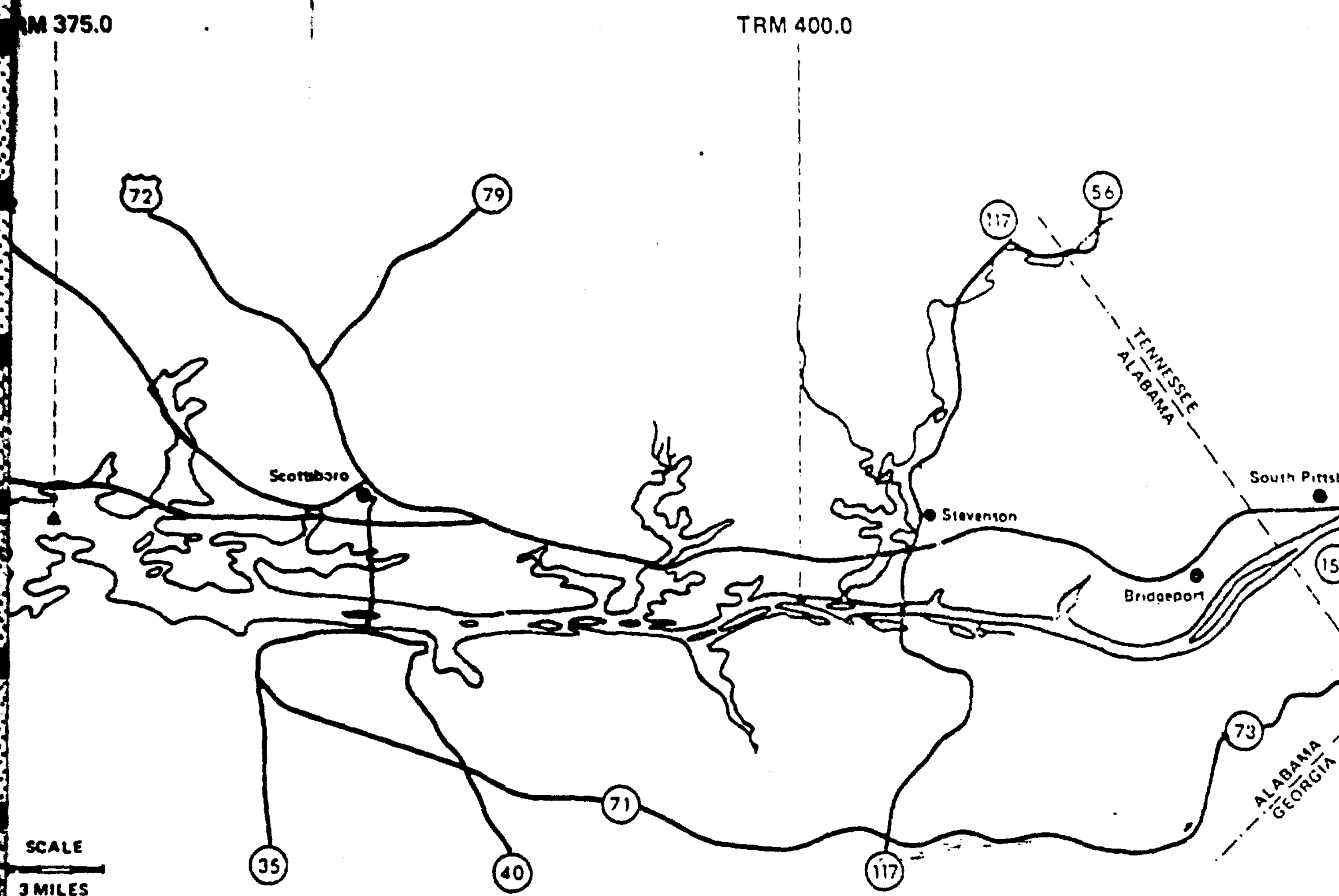


FIGURE 3. Tennessee River, Guntersville Reservoir

SOURCE: WATER AND AIR RESEARCH, INC., 1980.



TENNESSEE RIVER
GUNTERSVILLE RESERVOIR

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Indian Creek and Adjacent Lands and Waters, Wheeler Reservoir, Alabama

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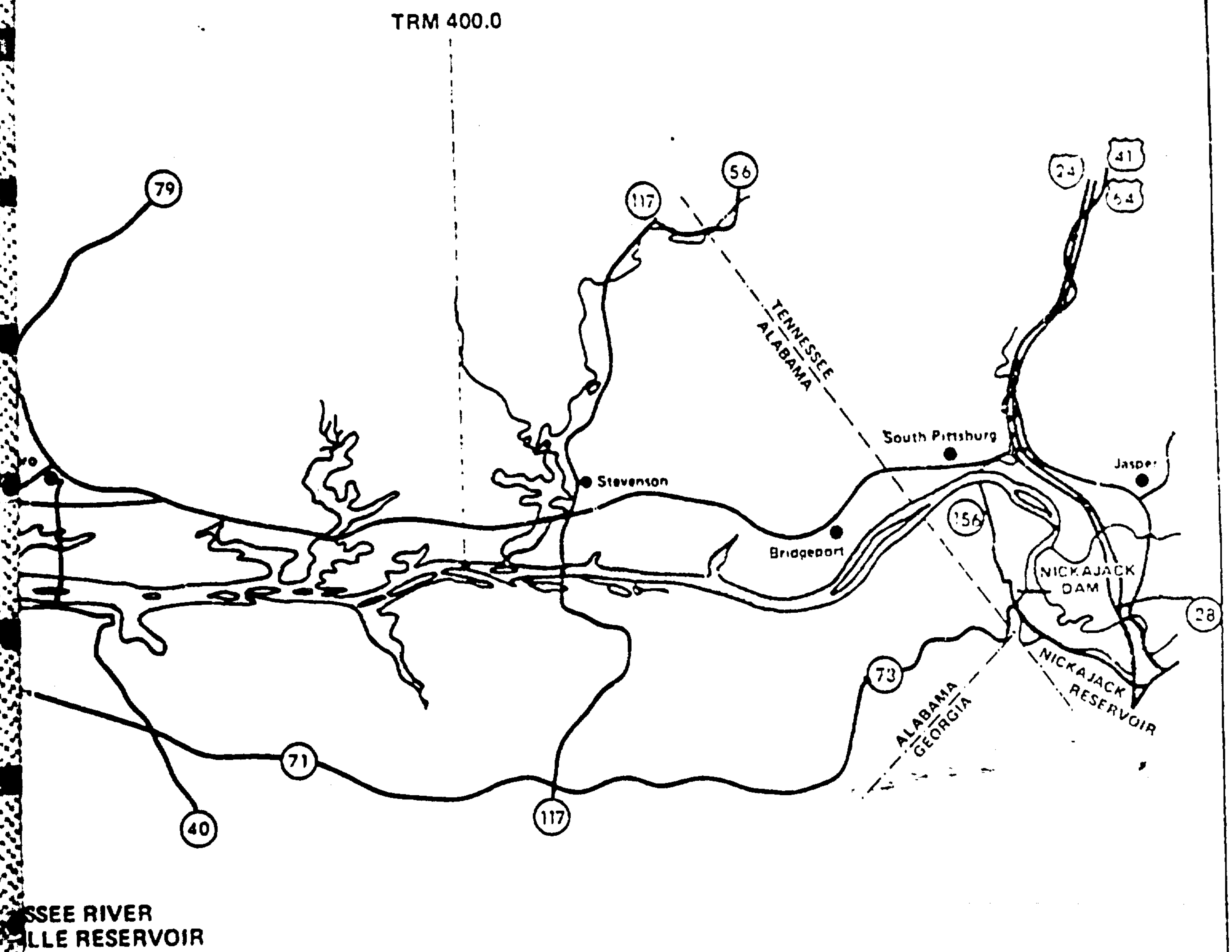

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production rates or waste generation. The plant capacity was approximately 25 million pounds per year. In 1954 Olin Mathieson Chemical Company became the lessee and continued DDT manufacture. Records do show a production rate of 2.25 million pounds per month for all or some part of 1969. Increasingly stringent effluent standards (20 parts per trillion) were a factor leading to the decision to discontinue DDT production in June, 1970.

2.2 WASTE TREATMENT HISTORY

No records were found indicating any type of wastewater treatment prior to 1965. In that year an effluent standard of 10 ug/l (parts per billion) was established by federal officials and a settling basin or tank was installed. It was reported that the basin frequently filled to overflowing with solids. In 1967 additional settling capacity was added. A new discharge ditch was constructed parallel to the old ditch, which was treated with lime and ferrous sulfate and filled in. In February 1970 carbon filtration was added. In 1970 the Federal Water Quality Administration lowered the effluent limit to 0.020 ug/l DDTR. Production was terminated by June 1970. Two other pesticides were later manufactured at the site; trichloroacetonitrile (TCAN) for less than a month and methoxychlor for about six months. The plant was demolished in early 1972.

2.3 RESTORATION WORK ON REDSTONE ARSENAL

Extensive restoration of the manufacturing site has been carried out. Initially, upstream drainage was diverted around the site. Runoff from the site was routed to the waste drainage ditch. Two retention dams were constructed in the ditch. A water filtration/carbon adsorption unit has been installed to treat water in this ditch. Surface soil at the old plant site was removed and buried in a State approved landfill located on Redstone. Excavation and landfilling of the contaminated sediments in the old ditch has been accomplished and stabilization of other DDTR disposal sites and installation and operation of a subsurface water monitoring system is being carried out. For purposes of the subject study, it was assumed that no further contamination of HSB would result from remaining DDTR on Redstone Arsenal.

2.4 HISTORICAL ENVIRONMENTAL CONTAMINATION

2.4.1 Water and Sediment

No records were found of environmental monitoring prior to 1963. At that time the U.S. Public Health Service sampled water and sediment in Huntsville Spring Branch, Indian Creek, and the Tennessee River. Elevated DDTR concentrations were observed particularly in Huntsville Spring Branch and Indian Creek. Comparison of sediment DDTR concentrations reported through the years shows no significant variation with time. Indian Creek values are roughly in the 10-50 ug/g (parts per million) range, Huntsville Spring Branch from Mile 0 to 2.4 in the 50-3,000 ug/g range, and Huntsville Spring Branch from Mile 2.4 to 5.4 in

the 100-25,000 ug/g range. The wide variation in the latter reach results in part from the unequal distribution of DDTR across the wide floodplain that exists there. So called "hot spots" exist in the channel and overbank in this reach which may or may not have been sampled in any particular survey. Overall, the existing historical data do not show any significant change in sediment concentrations in Indian Creek and Huntsville Spring Branch from 1963 to 1979.

2.4.2 Fish and wildlife

The first testing for DDTR in biota appears to have occurred in 1964. Wildlife collected near Huntsville Spring Branch included crows, swamp and cottontail rabbits, opossum, and gray fox. All species except the rabbits had average DDTR concentrations over 10 ppm in muscle tissue. One crow had 119 ppm DDTR.

As early as 1955, bird population estimates for Wheeler Wildlife Refuge showed a decline in Double-crested Cormorant populations. Other species, particularly raptorial birds, showed declines in the 1960's. DDTR may have been a factor in some of these declines but there is not sufficient data to establish such a relationship. Even if DDTR were a factor, nationwide or even regionwide agricultural usage may have been more important than the DDTR in HSB and IC.

The first reported fish survey data are from 1970. At that time white bass and channel catfish in Wheeler Reservoir had fillet DDTR concentrations up to 8.5 and 22.2 ppm respectively. In 1971, a statewide survey reported elevated levels of DDTR in fish from the Tennessee River. Analyses were made in the 1975-77 period on dressed fish from markets in the area. Most fish had DDTR levels below the 5.0 ppm FDA limit but one catfish had 115 ppm. In 1977, three surveys were made in the area. Whole body analyses were performed and many fish from the HSB-IC area had concentrations over 100 ppm. Similar results on other whole body analyses were obtained on fish sampled between 1977 and 1979. In 1977 and 1978 analyses performed on fillet samples showed high DDTR concentrations with several samples over 100 ppm. Consistently, the higher concentrations were found in the HSB-IC area and the TR within 10 miles of the IC confluence.

3.0 PRESENT SITUATION

3.1 DISTRIBUTION OF DDTR

3.1.1 Sediments

Huntsville Spring Branch and Indian Creek--The mass distribution of DDTR in IC and HSB is shown in Table 1. About 97.8 percent of the DDTR is located upstream of Dodd Road in HSB. Another 1.4 percent is in HSB between Dodd Road and IC. About 0.8 percent of the total is in IC.

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Table 1. Distribution of DDTR In Sediments

Location	Depth	DDT	DDD	DDE	DDTR
		Tons as DDT			
Upstream of Dodd Road	0-6"	90.4	45.0	19.7	155
	6-12"	105	35.9	14.6	156
	12-24"	86.0	22.5	6.4	115
	>24"	33.1	5.2	1.0	39.3
TOTAL		315	109	41.7	465
Dodd Road to Mouth of Huntsville Spring Branch	0-6"	2.1	1.9	0.63	4.6
	6-12"	0.54	0.79	0.36	1.7
	12-24"	0.12	0.12	0.07	0.31
	<24"	0.00	0.00	0.00	0.00
TOTAL		2.76	2.81	1.06	6.61
Indian Creek	0-6"	0.54	0.84	0.60	2.0
	6-12"	0.16	0.26	0.27	0.69
	12-24"	0.17	0.33	0.33	0.83
	>24"	0.01	0.01	0.00	0.02
TOTAL		0.88	1.44	1.20	3.54
OVERALL TOTAL		318	113	44	475

Note: All results have been rounded to no more than three significant figures.

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About 34 percent of the DDTR is contained in the top six inches of sediment and about 67 percent is in the top 12 inches.

The DDTR areal distribution in pounds per acre for the most contaminated area of HSB is shown in Figure 5. The most contamination exists in the channel and overbank upstream of Dodd Road (HSBM 2.4).

DDTR concentrations in stream bottom and overbank samples are shown in Table 2.

Tennessee River (Excluding Huntsville Spring Branch and Indian Creek)--Detectable quantities of DDTR were found in all (9 total) surface sediment samples in the Tennessee River from Mile 300 in Wheeler Reservoir to Mile 260 in Wilson Reservoir. Hard or rock bottom conditions precluded sediment sampling at some locations. The average concentration actually detected was 0.08 ppm with a range of 0.05 to 0.10 ppm. If isomers not detected were considered at stated detection limits, the average would increase to 0.18 ppm with a range of 0.16 to 0.19 ppm.

No DDTR was detected in four samples from TRM 320.8 to 375.

Detectable concentrations of DDTR were found in three of seven tributaries to Wheeler Reservoir. Two, Limestone Creek and Spring Creek, are located below Indian Creek and the other, Paint Rock River, above.

Total estimated DDTR amounts in sediments, excluding HSB-IC, is as follows:

	Tons
Tennessee River Mile 275-300	1.4 - 1.9
Wilson Reservoir	0.4 - 0.9
Other TR Tributaries	0.04 - 0.12
Total	1.8 - 2.9

3.1.2 Water

In the Tennessee River samples taken in July-August 1979 were below analytical detection limits. In December 1979 low but detectable (generally < 1ug/l) quantities were found, primarily in water samples taken near the bottom. Sampling during storms in the IC-HSB system showed DDTR concentrations up to 17.8 ug/l, most of which was associated with the suspended solids. Overall, the amount of DDTR that can be expected in the water column in Wheeler Reservoir at any one time is estimated to be less than 0.3 tons to not over 1 ton.

3.1.3 Biota

Estimates were made of the total DDTR contained in the following groups: macroinvertebrates, birds, fish and other vertebrates. The area included

Table 2. Summary of Stream Bottom and Overbank Sediment DDTR Concentrations in Indian Creek, Barren Fork Creek and Huntsville Spring Branch, August 1979.

Location	Depth Horizon	No. Samples	Sediment DDTR Concentration[1] (ppm as DDT) Mean	Range
ICM 0-5	0-6"	18	17.8	<1.01 - 30.8
	6-12"	10	8.88	4.65 - 15.2
	12-24"	10	5.83	<0.81 - 15.8
	>24"	3	0.61	<0.16 - 1.51
	Overall		8.75	<0.16 - 30.8
HSBM 0-2.4	0-6"	15	97.8	<2.26 - 403
	6-12"	14	9.99	<0.13 - 42.1
	12-24"	8	3.30	<0.37 - 9.77
	>24"	2	0.72	<0.66 - 0.78
	Overall		38.1	<0.13 - 403
HSBM 2.4-5.4	0-6"	54	1,360	<0.86 - 14,700
	6-12"	45	2,160	<0.09 - 30,200
	12-24"	28	299	<0.19 - 2,730
	>24"	3	1,820	<0.38 - 12,100
	Overall		1,540	<0.09 - 30,200
HSBM >5.4	0-6"	3	0.63	0.63
	6-24"	3	0.48	0.48
	12-24"	3	0.30	0.30
	Overall		0.47	0.30 - 0.63
Floodplain[2]	0-6"	11	0.95	<0.13 - 2,420
BFC	Overall		<0.94	<0.94

NOTES:

[1] All less than values assumed equal to stated value.

[2] Mean excludes station HSB FP 1, floodplain station near mouth of "Old Waste Ditch", and includes "Floodplain" stations in Indian Creek.

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for fish and macroinvertebrates was Wheeler Reservoir. For birds and other vertebrates, Wheeler Na[illegible] Wildlife Refuge was considered. Because precise data are not av[illegible]lable for either total populations or average DDTR concentrations, these data should be considered only as best estimates. The purpose of this data is to show the total amount of DDTR in biota for comparison with amounts in other substrates. The biological significance of DDTR in biota is discussed in other sections of this report.

Organism	Total DDTR Pounds	Total DDTR Tons
Macroinvertebrates	14	0.007
Fish	34 to 340	0.017 to 0.17
Birds	2	0.001
Other Vertebrates	6	0.003
Total	56 to 352	0.03 to 0.18

3.1.4 Overall Distribution of DDTR

Overall, the DDTR is contained predominately in sediments as shown below.

Substrate	Location	Tons DDTR	% of Total
Sediments	HSB-IC	475	99.4
Sediments	Wilson and Wheeler excluding HSB-IC	1.8 - 2.8	0.4 - 0.6
Water		<0.3 - 1.	<0.06 - 0.2
Biota		0.03 - 0.18	<0.006 - 0.04
Total		477 - 479	100

3.2 CURRENT CONTAMINATION LEVELS

3.2.1 Plankton

No accurate analysis of DDTR in plankton could be made as it was not possible to separate the plankton from inorganic suspended solids which also contained high concentrations of DDTR.

3.2.2 Macroinvertebrates

A strong relationship between DDTR concentration in macroinvertebrates and location relative to contaminated sediments is evident. In the Tennessee River macroinvertebrate DDTR concentration ranged from 0.02 to 0.50, in Indian Creek from 24 to 355, and in Huntsville Spring Branch from 2.5 to 2,710 ppm.

Table 4. Summary of DDTR Results of July-October 1979 Fish Survey

Location	Channel Catfish	Smallmouth Buffalo	Largemouth Bass	Bluegill
CCM 2	56(3.3-139)	0.15	0.352	0.25
ERM 5	1.2(0.4-2.3)	1.35	0.05	0.05
ERM 10	0.55	1.1	0.05	0.05
ERM 15	0.4	0.25	0.05	0.05
FCM 5	3.75(0.15-19.1)	0.25	0.15	0.2
FRM 1	0.5(0.1-2.6)	---	0.05	0.05
ICM 2	186(15.5-627)	16.2(2.2-44)	1.4[2]	4.2(2.1-6.6)
LCM 3	4.3	5.4(0.25-1.1)	0.15[2]	0.15
PRRM 1	0.2(0.2-2.6)	0.4	0.05	0.05
SCM 1	1.95	1.1	0.05	0.05
TRM 260	0.6	---	0.1	0.05
TRM 265	---	---	0.05	0.1
TRM 270	1.3	1.6	0.15	0.2
TRM 275	1.8(1.2-10.1)	3.9	0.05[2]	0.15
TRM 280	0.7	2.8	0.05[2]	0.1
TRM 285	---	0.7	0.25	0.05
TRM 290	2.0(0.45-2.2)	5.1(0.25-4.5)	0.15	0.05
TRM 295	1.9	2.1	0.10	0.05
TRM 300	12.5(1.4-46.3)	0.9	0.4	0.05[2]
TRM 305	12.8(1.3-21.0)	0.3	0.15[2]	0.05[2]
TRM 310	1.2	3.2	0.15[2]	0.2
TRM 315	[4]9.1(3.0-40.0)	2.75	9.2[2](0.5-3.1)[1]	0.25
TRM 320	9.6(0.8-22.0)	1.2	2.8	0.7
TRM 325	0.3	1.3	6.0	0.15
TRM 330	0.35	0.9	2.3(0.55-16.1)	0.1
TRM 335	0.35	0.6	7.3(1.9-11.9)	0.05
TRM 340	1.2	0.7	0.8[3]	0.1
TRM 345	1.2(0.8-3.7)	0.5	1.5	0.05
TRM 350	---	---	0.25	0.05
TRM 375	0.15	0.5	0.05	0.05
TRM 400	---	0.6	0.05	0.05

Notes: First number is DDTR concentration in a six fish composite. Concentration in ug/g.
Numbers in parenthesis are range of results from individual fish analyses.
Fillet samples for all species shown.
TRM 260-270 in Wilson Reservoir.
TRM 350-400 in Guntersville Reservoir.
All other sites in Wheeler Reservoir.

[1]Only two individuals analyzed.
[2]Results may be low - run on 12 December. See Quality Assurance Document.
[3]EPA got 9.4 for this sample.
[4]EPA got 25.4 for this sample.

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Table 5. Summary of DDTR Results of June-July 1980 Fish Survey

Location	Species	Composite Sample	Individual Fish Samples Average	Range
TRM 275	CC	9.3	11	4.5-25
TRM 280	CC	8.5	8.5	5.5-13
TRM 285	CC	15	9.5	2.8-19
TRM 290	CC	15	13	3.5-22
TRM 295	CC	15	14	4.7-31
TRM 300	CC	9.0	11	3.0-18
TRM 305	CC	10	14	9.7-22
TRM 310	CC	9.2	9.2	3.8-17
TRM 315	CC	5.4	7.6	3.3-13
TRM 320	CC	120	120	13-360
TRM 325	CC	100	190	0.74-1100
TRM 330	CC	34	32	2-140
TRM 340	CC	25	33	1.5-180
FCM 5	CC	50	45	10-150
LCM 3	CC	14	13	2-28
SCM 1	CC	5.8	5.0	2.6-9.1
TRM 280	SMB	6.4	3.9	2.3-6.8
TRM 290	SMB	12	10	3.4-21
TRM 300	SMB	6.3	5.0	1.3-10
TRM 310	SMB	4.3	4.0	1.4-6.1
TRM 320	SMB	25	24	0.43-48
TRM 330&340	SMB	0.89	0.95	0.25-2.5
TRM 285	LMB	0.38	0.36	0.11-0.80
TRM 345	LMB	2.1	2.4	0.35-7.4

Concentrations in ug/g

CC=Channel Catfish, SMB=Smallmouth Buffalo, LMB=Largemouth Bass.

Six individual fish were taken at each sampling location. All analyses were in fillet samples.

Smallmouth buffalo appear to be contaminated, particularly at and downstream of IC. Largemouth bass have lesser overall contamination but some individual fish had relatively high DDTR levels.

Method of Contamination--The source of contaminated fish in the Tennessee River is of significant concern. Several possibilities exist. The river could contain sufficient DDTR residues from IC-HSB or from other sources to contaminate fish. The contamination could result from fish becoming contaminated in IC-HSB and migrating out into the river.

Sediment analyses clearly show the IC-HSB system as being a major source of DDTR. Further, it has been shown that at least some DDTR is being transported out of the IC-HSB system to the TR. Sediment and water analyses for the TR and tributaries indicate no other significant source of DDTR.

Except for the unexplained high levels in channel catfish at Flint Creek Mile 5, the pattern of contamination for individual fish in the June-July 1980 survey also suggests HSB-IC as the primary source of DDTR. Downstream of IC more than 80 percent of the catfish had DDTR levels above 5 ppm. It seems likely that such a consistent pattern of contamination would result from in situ conditions rather than migration. Above IC individual fish concentrations were more variable and suggested migration as a likely source of upstream contamination.

3.2.4 Birds

Current data for DDTR in Green Herons and Wood Ducks from TRM 271 to 402 are reported in this study. Birds from the IC-HSB area had almost an order of magnitude higher DDTR concentration than birds from other parts of the study area. Both Crows and Mallard ducks collected in February 1979 had geometric mean DDTR concentrations of 4.0 ppm in muscle tissue. Mallard wing analyses for the 1978-79 hunting season showed order of magnitude higher DDTR levels for birds from Limestone and Madison Counties as compared to other Alabama counties surveyed. The Arsenal is in Madison County and Limestone is the next county west.

3.2.5 Mammals

DDTR levels in shrews were 52 ppm in HSB and no higher than 7.7 ppm in five other areas. Muskrats from HSB had 0.26 ppm DDTR and less than half that in five other areas. Cottontail and swamp rabbits from the Arsenal contained mean concentrations of 0.27 and 0.25 ppm DDTR.

3.2.6 Reptiles

Snapping turtles and water snakes from HSB had DDTR concentrations of 0.45 and 1.8 ppm respectively. These were the highest values reported in samples from this area.

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3.2.7 Vascular Plants

Buttonbush samples from HSB had a DDTR concentration of 0.065 ppm compared to 0.005 ppm at TRM 359 upstream. Duckweed from the most contaminated stretch of HSB had concentrations as high as 5.6 ppm. Hibiscus was found to contain 0.786 ppm DDTR in HSB compared to 0.004 ppm at TRM 359.

3.3 ENVIRONMENTAL TRANSPORT OF DDTR

Of particular concern in evaluating the current situation and predicting future conditions is the stability of the DDTR now in the system. Is the contamination spreading and if so, how? Or is the DDTR degrading and/or becoming isolated from the rest of the environment? Two means of transport were considered, physical and biological.

3.3.1 Physical Transport of DDTR

Because the vast majority of DDTR is found in the sediments, processes which would tend to move sediments were of particular interest. Thus sediment transport, particularly during high flow storm events, was expected to be important. Sampling was carried out during a number of storm events at four locations in the HSB-IC system to evaluate DDTR transport. Measurements, including rainfall, stage, discharge, suspended solids, volatile suspended solids as well as suspended (i.e., passing a 63u sieve and retained on a ~1u glass fiber filter) and dissolved/suspended (i.e, passing a ~1u glass fiber filter) DDTR concentrations, were made a number of times during each storm runoff event. Usable data were obtained from three storm events.

In order to estimate DDTR transport rates, multiple regression models were developed relating suspended DDTR transport rates to sampling locations, discharge, type of runoff event (i.e., headwater or tailwater) and the transport rate of the corresponding suspended solids loading rate (i.e., <63u and >1u) and relating dissolved/suspended DDTR transport rates to sampling locations, discharge and the volatile suspended solids loading rate (i.e., <63u and >1u). Seasonal and annual flow duration relationships were developed at each sampling location, the seasons winter (November-April) and summer (May-October) being defined with respect to Wheeler Reservoir operational procedures. Suspended and volatile suspended solids loading rates were related to sampling location and discharge utilizing multiple regression techniques. The frequency with which tailwater runoff events occurred in the lower reaches of HSB-IC were estimated from an examination of the regional topography and seasonal stage duration relationships developed for the Tennessee River at Whitesburg, Alabama. The combination of these data yielded estimates of the seasonal and annual DDTR transport rates within and out of the IC-HSB system. Predicted annual DDTR transport rates and 95 percent confidence limits are as follows:

Location	DDTR Loading (tons/yr as DDT)	95% Confidence Limits (tons/yr as DDT)
Upstream of Old DDT Waste Ditch:		
HSBM 5.9	0.01	0.006 to 0.05
Downstream of Old DDT Waste Ditch:		
HSBM 2.4	0.62	0.25 to 1.6
ICM 4.6	0.99	0.44 to 2.2
ICM 0.9	0.64	0.31 to 1.3

As these figures indicate, DDTR is being scoured upstream of Dodd Road and is being transported downstream to the Tennessee River. Over two thirds of the DDTR transport out of the IC-HSB system occurs during the winter months (Nov-April). The DDTR load to the Tennessee River is about equally divided between the suspended fraction, associated with silt and medium and coarse clay sized materials, and the dissolved/suspended fraction, either dissolved or associated with fine clays and colloidal material. It should be noted, that at the rate at which the DDTR contamination in the IC-HSB system is being transported to the Tennessee River by fluvial transport processes, i.e., 0.07 to 0.27 percent per year, it will take centuries to flush the system.

3.3.2 Biological Transport of DDTR

Compared to sediment amounts, the very low total amounts of DDTR in the biota make biological transport an unimportant factor in the overall dispersion of DDTR. However, food chain links can be an important mode of contamination for biota.

4.0 ALTERNATIVES FOR MITIGATION OF DDT CONTAMINATION IN HUNTSVILLE SPRING BRANCH AND INDIAN CREEK

4.1 INTRODUCTION

Six alternatives are presented for mitigation of DDTR contamination in HSB and IC. They are:

A) Natural Restoration,
B) Dredging and Disposal,
C) Out-of-Basin Diversion and Removal of Contaminated Sediments,
D) Out-of-Basin Diversion and Containment of Contaminated Sediments,
E) Within-Basin Diversion and Removal of Contaminated Sediments, and
F) Within-Basin Diversion and Containment of Contaminated Sediments.

A number of other alternatives, including in-place stabilization or detoxification and impoundment structures, were considered but proved not to be feasible.

These alternatives do not deal with DDTR contamination in the TR. Concentrations of DDTR in the TR sediments are approximately two orders of magnitude below those in IC, being on the order of non-detectable to 0.2 ppm compared to typical concentrations of 10 to 30 ppm in IC sediments.

Because of these low concentrations and the large area over which low-level contamination is dispersed in the TR, mitigation alternatives there appear to be economically infeasible. The relatively high (10 to 30 ppm) concentrations of DDTR in IC channel sediments warrant consideration of mitigation alternatives in IC upstream to the HSB confluence. It is apparent that this level of contamination is a major source of DDTR in fish inhabiting IC and the TR. Due to the flows encountered in IC and the infeasibility of containment alternatives there, the only practical means of dealing with this contamination is by dredging the sediments. With the exception of the natural restoration alternative, all alternatives presented include the dredging of IC in addition to mitigating contamination in HSB.

Presentation of the alternatives will begin with a discussion of relevant properties of DDT and physical characteristics of the study area. These considerations are of paramount importance in assessing the effectiveness and environmental acceptability of the alternatives.

Alternatives B through F are centered around one or more of four major physical actions; dredging and disposal, an out-of-basin diversion of HSB, a within-basin diversion of HSB, and in-place containment of contaminated sediments. To avoid redundancy in discussing the alternatives, these four major actions will be discussed first on an individual basis, along with their respective impacts. Each complete alternative will be discussed in a later section and the major physical actions associated with it will be referenced to the earlier discussions. Separate sections appear for areawide environmental monitoring and legislation, regulations, and permitting associated with the alternatives. A summary comparison of alternatives is presented in the final section.

4.2 CHARACTERISTICS OF DDT-SEDIMENT ASSOCIATION

4.2.1 Introduction

The approach taken in this study is to design a technically feasible and environmentally sound course of action with respect to alternatives for removal, containment, and disposal of DDTR-contaminated sediments. The effectiveness of each alternative is dependent on the properties of DDTR and the sediments with which it is associated. The purpose of this section is to summarize those properties which form the basis of the removal, containment, and disposal alternatives presented.

4.2.2 DDT Mobility in Sediments

All DDTR isomers are extremely hydrophobic, their solubility in water being on the order of 1.2 ppb. Numerous researchers have reported the

Table 6. Estimated DDTR Contained in Designated Hydrologic Areas of Huntsville Spring Branch and Indian Creek

Reach	Miles Included	Area Hydrologic Designation	Surface Area (sq yd)	Volume of Sediment Contained in 3-ft Depth Over Designated Area (cu yd)	Estimated Mass of DDTR in Designated Area (tons)	Estimated % of Total[1] DDTR in Designated Area	Typical Range of DDTR Concentration Encountered In Designated Area (ppm)
A	HSB Miles 5.6-2.4	Channel[2]	228,000	228,000	327	69	100-30,000
		Critical Overbank[3]	364,500	364,500	131	28	100-15,000
		Noncritical Overbank[4]	879,500	879,500	5.15	1.1	5-40
		Ponded[5]	293,000	293,000	1.50	0.32	1-5
B	HSB Miles 2.4-0.0	Channel	408,000	408,000	6.27	1.3	10-400
		Overbank	313,000	313,000	0.28	0.06	2-7
		Ponded	231,000	231,000	0.15	0.03	1-5
C	IC Miles 0.0-5.4	Channel	615,000	615,000	2.98	0.63	10-30
		Overbank	50,000	50,000	0.14	0.03	0-1
		Ponded	614,000	614,000	0.57	0.01	0-1

1. "Total" refers to the total estimated DDTR contained in HSB and IC, 475 tons.
2. Channel areas are designated as the inundated areas in the active flow regime at a pool elevation of approximately 555 feet. The channel is nearly bank-full at this elevation and is typified by well-defined banks and the absence of vegetation occurring in the overbank.
3. The immediate floodplain in HSB and IC inundated by high pool stage in the Wheeler Reservoir is designated as overbank. High DDTR levels in sediment cores from the critical overbank indicate that this area contains a significant fraction of DDTR in the HSB-IC system.
4. DDTR levels in the noncritical overbank are typically orders of magnitude less than those observed in the critical overbank, but still sufficiently high to warrant consideration of mitigation alternatives there.
5. Sloughs in HSB and IC which are permanently inundated but not subjected to normal channel flow are designated as ponded.

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Table 7. Areal Dredging Plans for Dredging Huntsville Spring Branch and Indian Creek Channel Sediments

Dredging Plan	Reaches Included[1]	Miles Included	Volume of Sediment To Be Removed (cu. yd.)[2]	Estimated % of Total[3] DDTR Contained in Volume
I	A	HSB Mile 5.6-2.4	228,000 - hydraulic 121,600 - dragline	96.4
II	A,B	HSB Mile 5.6-0.0	636,000 - hydraulic 121,600 - dragline	97.7
III	A,B,C	HSB Mile 5.6- IC Mile 0.0	1,251,000 - hydraulic 121,600 - dragline	98.4
III plus Noncritical overbank	A,B,C	HSB Mile 5.6- IC Mile 0.0	1,251,000 - hydraulic 1,244,000 - dragline	99.4

1 Reaches designated in Table III-1 and shown in Figure III-7.
2 Figures based on removing 3 ft. of sediment from the channel
3 "Total" refers to the total estimated DDTR contained in HSB and IC

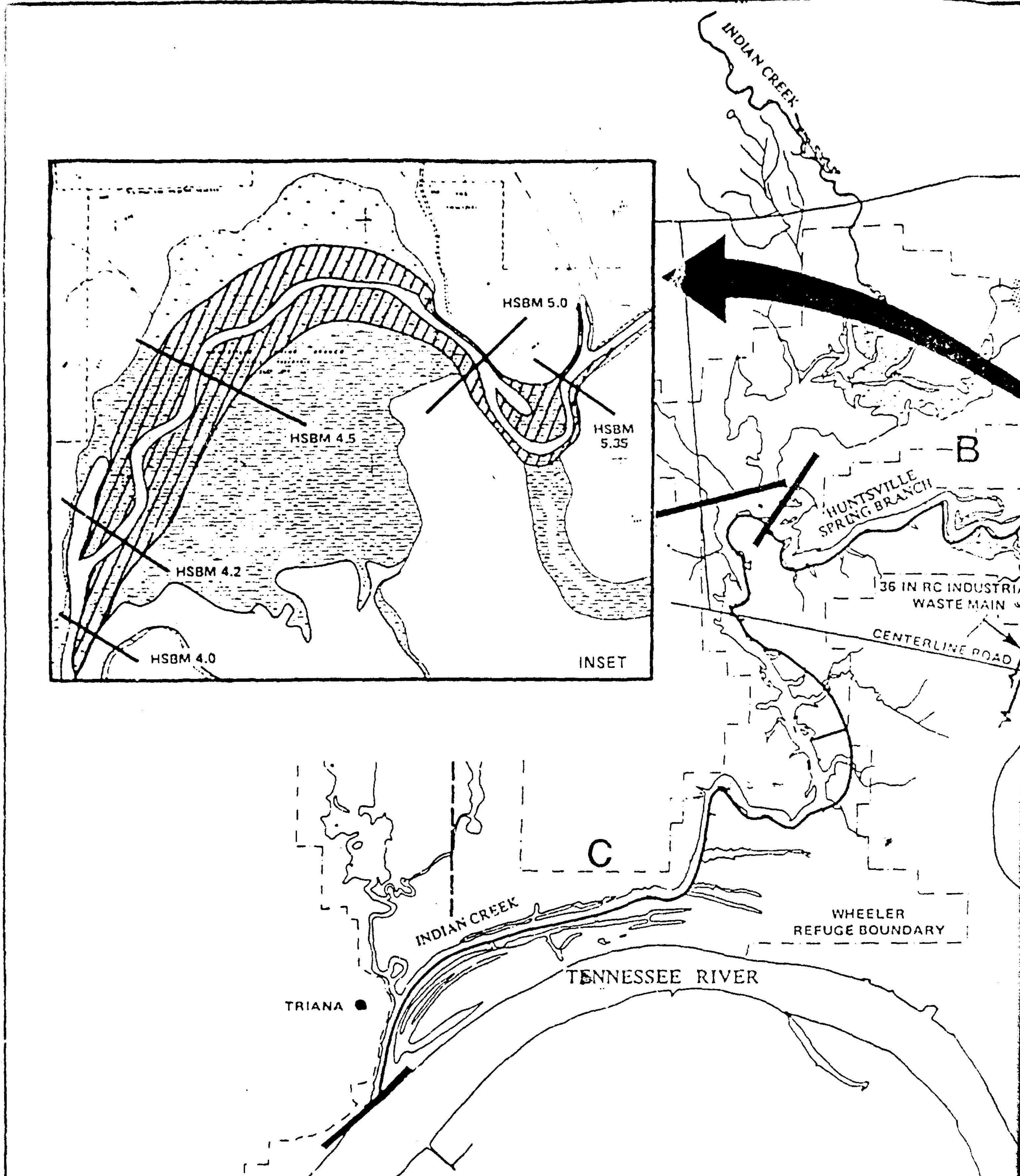
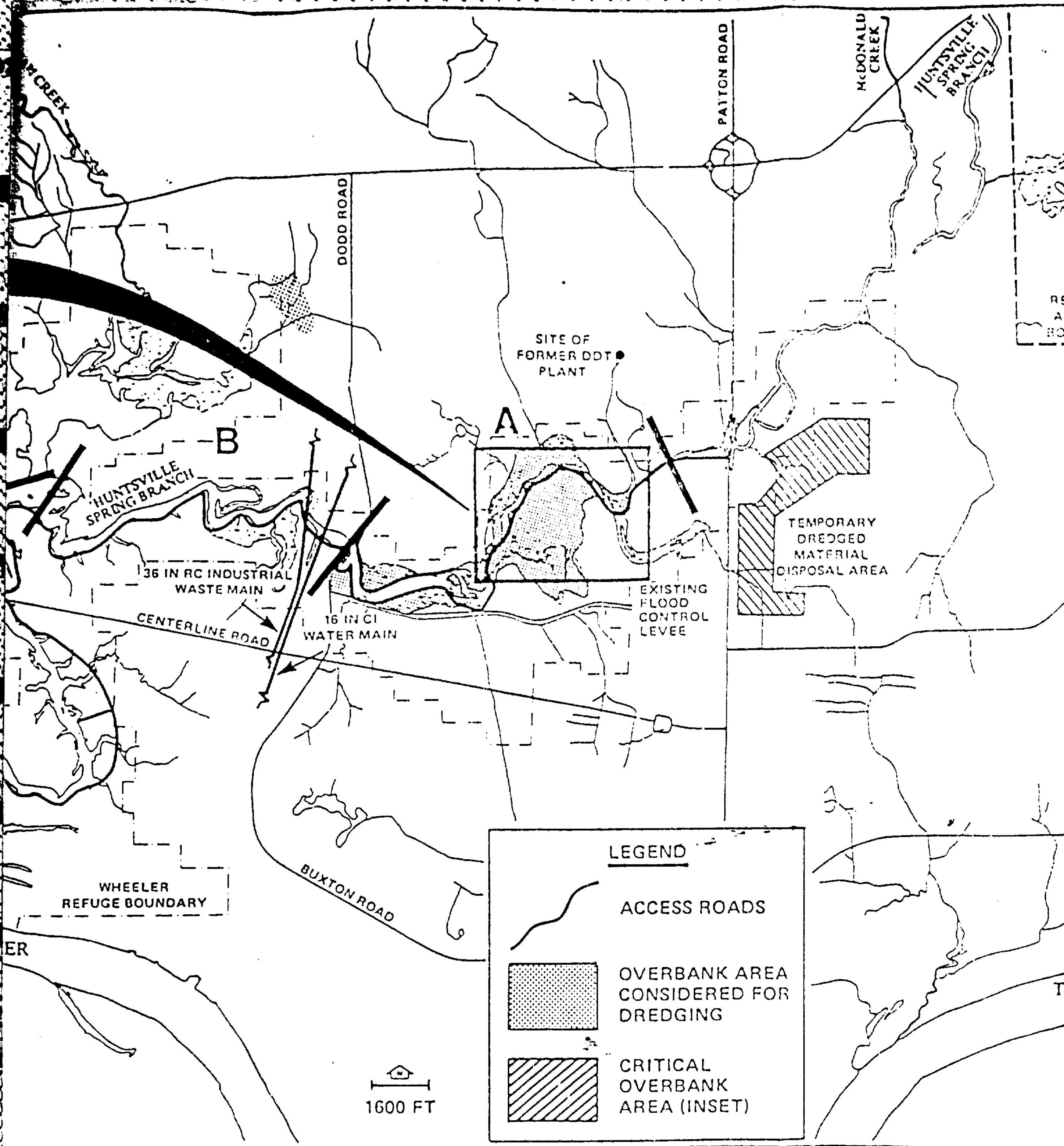


FIGURE 6. Areal Plan for Hydraulic Dredging in Huntsville Spring Branch and Indian Creek

SOURCE: WATER AND AIR RESEARCH, INC., 1980



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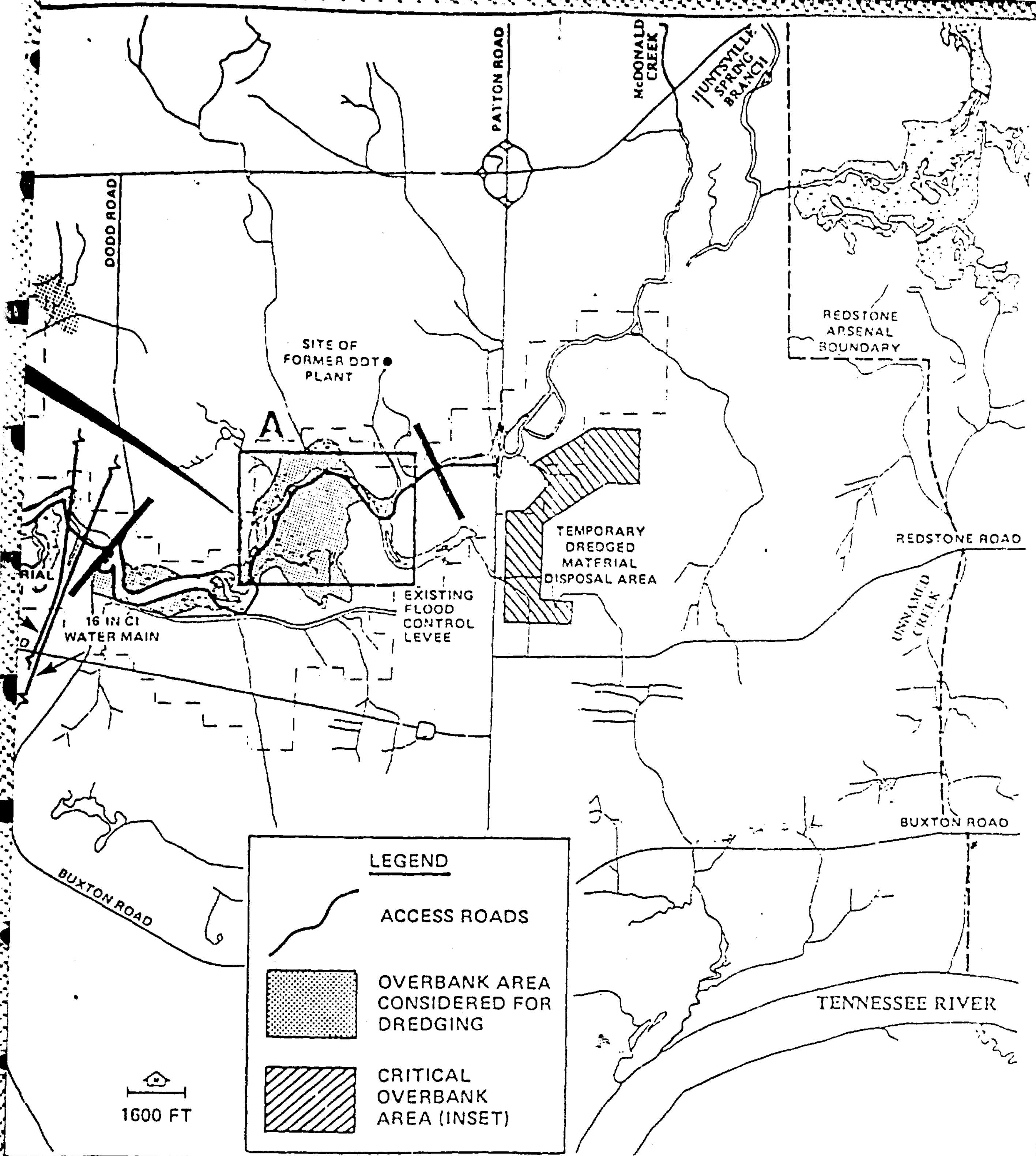

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are dewatered. Factors favoring the environmental acceptability of this disposal technique are summarized in Section 4.2. Another option considered is to dispose of the dewatered material in an abandoned mine, prepared in such a manner as to effectively isolate the contaminated sediments.

4.3.2 Temporary Dredged Material Disposal Area (TDMDA)

Introduction--To implement a dredging alternative it will be necessary to site a temporary dredged material disposal area within reasonable pumping distance from the areas to be dredged. The disposal area must be carefully designed to assure containment of the contaminated sediments and to provide for adequate treatment of the overflow water. The location of the preliminary selected TDMDA is indicated in Figure 6.

Return Water Treatment System--Treatment of the return water will be necessary before it is discharged to HSB. The proposed treatment system is designed for complete solids removal with carbon adsorption to remove soluble DDTR. Disposal areas sized for Dredging Plans I and II will require 2 MGD capacity and that sized for Dredging Plan III will require 3 MGD.

Dewatering Dredged Material--Dewatering of the dredged material will be necessary before an ultimate disposal option can be carried out, be it on-site application of a stable impermeable cover, or transportation of the material to off-site mine disposal.

A series of studies conducted by the U.S. Army Engineer Waterways Experiment Station under the Dredged Material Research Program concluded that natural evaporative drying with progressive trenching is the most efficient and cost-effective method of dewatering fine-grained dredged material. Other methods investigated were the use of underdrains, horizontal or vertical sand drains, mechanical agitation, electro-osmosis, and vacuum well pointing. While some of these methods produce higher rates of dewatering, they incur high capital and operating costs and are not cost-effective unless constraints, such as time available, preclude natural dewatering.

4.3.3. Dredging HSB and IC Sediments

Overview-- Channel dredging will proceed in the following sequence:

1) construct necessary access roads along HSB,

2) clear trees and other debris from the channel and bank edges with a crawler-mounted crane operating from the access road and a small barge-mounted crane operating in areas inaccessible from the road,

3) dispose of the cleared debris in a landfill, and

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4) hydraulically dredge the channel sediments and transport material via pipeline to the temporary disposal area.

For removing overbank material in Reach A of HSB, the following approach will be used:

1) clear vegetation from the overbank,

2) grub all root systems,

3) remove contaminated sediment with a dragline,

4) construct haul roads as necessary as operation progresses into overbank,

5) dispose of contaminated tree material in landfill, and

6) dispose of contaminated sediment by landfilling in the TDMDA, or by burial in an off-site mine.

Channel Dredging--A conventional basket cutterhead dredge such as the 14-inch Ellicott 770 could be employed to dredge HSB and IC channel sediments. Dredging will commence at HSB Mile 5.6 as soon as sufficient channel is cleared and proceed downstream, following the snagging operation.

Due to the long discharge distance to the TDMDA (12.5 miles from IC Mile 0.0) a total of 11 booster pumps will be required in the discharge line. Use of electric boosters is recommended, as they are much more easily adapted to an integrated central control system to maintain steady flow in the discharge line. A temporary power line carrying primary voltage (43 kv) would be required along the access road to provide power for the boosters. Spacing power poles at 175 foot intervals and installing conventional street lights on each would provide adequate lighting along the access road for evening shift work and pipeline inspection.

Overbank Removal--The critical overbank area indicated in Figure 6 consists of approximately 25 acres and contains an estimated 28 percent of the total DDTR in the HSB-IC system. Its removal will require excavation and disposal of 121,600 cubic yards of sediment. The non-critical overbank areas of Reach A contains approximately 1.1 percent of the total DDTR in the HSB-IC system. In order to remove this 1.1 percent, approximately 235 acres of overbank will have to be cleared and grubbed, and 1,122,400 cubic yards of sediment will have to be excavated.

Removal of the overbank sediments will require clearing all vegetation and grubbing all root systems. Disposal of cleared uncontaminated timber and debris will be provided by the contractor hired for clearing. Removal of the contaminated sediments to a depth of 3 feet can be accomplished simultaneously with grubbing by a small dragline, operating

8) Section 26a of the Tennessee Valley Authority Act,
9) Various Historic and Archaeological Data Preservation Laws,
10) Alabama Hazardous Wastes Management Act of 1978,
11) Alabama Air Pollution Control Act of 1971,
12) Occupational Safety and Health Administration Legislation,
13) Executive Order 11988, and
14) Executive Order 11990.

4.9 PROPOSED ALTERNATIVES

4.9.1 Alternative A: Natural Restoration

With this alternative, mitigation of DDTR contamination would be left to natural processes. The key question with this alternative is will the situation get better or worse if left alone? For the situation to improve, one of three things must occur. Either

1) the DDTR must be degraded to harmless compounds, or

2) the DDTR must become isolated in some manner from the rest of the environment, or

3) the DDTR must be flushed out of the system.

Based on the known persistence of DDTR, particularly at the concentrations found in HSB, the natural degradation rate will be slow. Half-life may easily be on the order of 20 to 30 years. If this is true, one would expect to have in excess of 50 tons of DDTR in this system 60 years from now. Thus, natural degradation appears to be only a very long term hope at best.

Natural isolation of the material from the rest of the environment may be possible. The most likely mechansism would be natural sediment deposition which could bury the DDTR. However, the old DDT plant has been closed for over 10 years and 34 percent of the DDTR is still within the top 6 inches of sediment, 67 percent within the top 1 foot. Thus, if significant natural sediment deposition is occurring, it is not readily apparent.

The third possible means of natural restoration would be for the DDTR to be flushed out of the system. Given the mass of DDTR in the HSB-IC system and the current estimates of transport rates, it appears that hundreds of years would be required to flush the system naturally. Even if this were to occur, the positive effects on the HSB-IC system would be more than offset by the negative impacts on the Tennessee River.

A further negative factor in assessing the potential effectiveness of this alternative is the relatively small amount of DDTR required to cause significant contamination. Currently, only 0.8 percent of the total DDTR is in Indian Creek and fish are contaminated. If the substantial storehouse of DDTR upstream is left uncontrolled, the threat always exists that contamination of IC will be maintained or even made worse.

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It may be that, given enough time, sufficient DDTR will move into the TR to cause even worse contamination problems there.

On a more positive note, there is the suggestion in some of the bird population data from Wheeler National Wildlife Refuge that some species adversely impacted by DDTR have been recovering in recent years. However, this recovery is not observed in many species. Also, it is not known whether the apparent recovery in some species is due to local, regional, or areawide conditions.

The short-term risk of natural restoration is relatively low in that the situation does not appear to be rapidly worsening. Thus, it would be possible to tentatively employ this alternative coupled with continued monitoring and status reports. This would allow additional time during which more definitive information could be gathered to determine contamination trends. Such a monitoring program should include measurement of DDTR levels in fish, sediment, water and to a more limited extent in animals and birds. Cost would be dependent on intensity and frequency of sampling but is roughly estimated at $600,000 per year.

The selection of the natural restoration alternative would have the advantage of providing time during which new and/or currently unproven technology could be developed which might result in a more cost effective mitigation plan. However, there is no guarantee that such a plan would materialize.

In summary, the success of the natural restoration alternative depends on natural actions that range in probability from very unlikely to, at best, possible. On the positive side, it appears that conditions are not rapidly changing and the tentative selection of this alternative would not present a high risk for a significantly worsened situation.

4.9.2. Alternative B: Dredging and Disposal

HSB and IC channel sediments would be hydraulically dredged to a depth of 3 feet. The critical overbank area would be dragline dredged to a depth of 3 feet. Non-critical overbank sediments may or may not be dredged. Hydraulically dredged sediments would be pumped to the TDMDA, where they would be dewatered. Dragline-dredged sediments would be truck-hauled to the TDMDA. The most feasible means of permanent disposal of contaminated sediments is closure of the TDMDA as a permanent landfill.

Implementation Summary--

1) Conduct cultural resources survey of impacted areas and implement necessary actions to recover or preserve valuable sites.

2) Construct temporary dredged material disposal area (TDMDA).

3) Secure lease on return water treatment system and set up at TDMDA

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4) Clear and grub critical overbank area, dredge those sediments with a dragline to a depth of 3 feet, and dispose of in TDMDA

5) Construct access roads along the channel and install 43 kv primary voltage power line with lighted poles

6) Clear all snags and debris from HSB and IC channels

7) Acquire 12, 14-inch booster pumps and install 11 of them at 6,000 foot intervals along access road (one used as spare)

8) Implement monitoring of dredging operation

9) Dredge HSB and IC channels with 14-inch cutterhead hydraulic dredge to a depth of 3 feet, beginning at HSB Mile 5.6. Pump dredged sediments to TDMDA

10) Dewater dredged material in the TDMDA

11) Permanently dispose of DDTR-contaminated sediments by closing TDMDA as a landfill

12) Implement areawide environmental monitoring and long-term monitoring and maintenance of the permanent disposal site.

Options Available With Alternative B--

1) Remove noncritical overbank sediments of Reach A to a depth of 3 feet

2) Delete carbon adsorption from return water treatment system

3) Remove dewatered sediments from TDMDA and dispose of in an abandoned mine

4) Delete dredging of Reach C (IC)

5) Delete dredging of Reaches B and C (HSB Mile 2.4 to IC Mile 0.0)

Cost Summary for Alternative B--The cost summary for Alternative B is in Table 8.

Impact Summary for Alternative B--The environmental impacts of dredging and disposal have been discussed in Section 4.3.6.

With regard to Cultural Resources, dredging impacts a large number of high probability locations in the proximity of HSB and IC. There is presently no way to predict accurately how many sites are located in the alluvial bottomlands of IC and HSB, now inundated by Wheeler Reservoir. Disposal of dredged material will impact a relatively smaller area with a high probability for site locations, as indicated by the reconnaissance survey.

Table 8. Cost Summary for Alternative B (As Detailed in Table III-11 for Dredging Plan III)

Dredging Plan	Reaches Included*	Total Estimated Cost (Millions of Dollars)
I	A	30.91
II	A,B	42.53
III	A,B,C	72.03

Estimated Effect of Other Options on Cost Estimate (Millions of Dollars):

-Implement Noncritical Overbank Removal Option	+ 14.57
-Delete Carbon Adsorption From Return Water Treatment System	- 4.16
-Implement Mine Disposal (Plan III)	+ 15.51
(Including Disposal of Noncritical Overbank Sediments)	+ 43.37

4.9.3 Alternative C. Out-of-basin Diversion and Removal of Contaminated Sediments

HSB would be diverted from 3 miles upstream of the highly contaminated area directly to the Tennessee River. Channel sediments between HSB Mile 2.4 and IC Mile 0.0 would be hydraulically dredged under near-zero flow conditions. The HSB channel between Miles 2.4 and 5.6 may be hydraulically dredged, or dredged with a dragline if the area is dewatered by construction of the containment dike illustrated in Figure 9. Critical overbank sediments would be dragline-dredged and non-critical overbank sediments may or may not be dredged.

Implementation Summary--

1) Conduct cultural resources survey of impacted areas and implement necessary actions to recover or preserve valuable sites.

2) Construct out-of-basin diversion of HSB and McDonald Creek cut-off channel.

3) Raise Patton Road to elevation 578 and construct dike northwest of Patton Road. This dike combination will serve as a diversion dike for HSB and will limit transport of contaminated sediments in HSB during removal operations

4) Construct TDMDA

5) Secure lease on return water treatment system and set up at TDMDA

6) Clear and grub critical overbank area, dredge those sediments with a dragline to a depth of 3 feet, and dispose of in TDMDA

7) Dredge HSB and IC channels by one of the two following methods:
   a) Hydraulic Dredging as summarized in items (5) through (9) of Section 4.9.2
   b) Construct western containment dike, drainage channel, and pumping station as shown in Figure 10 and excavate sediments within the containment area (HSB Miles 2.4 to 5.6) to a depth of 3 feet with a dragline. Dispose of sediments in TDMDA. Dredge sediments downstream from HSB Mile 2.4 hydraulically as summarized in items (5) through (9) of Section 4.9.2.

8) Dewater dredged material in TDMDA

9) Permanently dispose of DDTR-contaminated sediments by closing TDMDA as a landfill

10) Implement areawide environmental monitoring and long-term monitoring and maintenance of the permanent disposal site.

Options Available With Alternative C--

1) Remove noncritical overbank sediments to a depth of 3 feet

2) Delete carbon adsorption from return water treatment system

3) Remove dewatered sediments from TDMDA and dispose of in an abandoned mine.

4) Delete dredging of Reach C (IC)

5) Delete dredging of Reaches B and C (HSB Mile 2.4 to IC Mile 0.0)

6) Use alternate alignment for out-of-basin diversion to maintain it within RSA boundaries

Cost Summary--The cost summary for Alternative C is in Table 9.

Impact Summary--The environmental impacts of out-of-basin diversion and of dredging and disposal have been discussed in Sections 4.4.5 and 4.3.6.

With regard to Cultural Resources, Alternative C impacts a large number of high probability locations. All probable or potential sites in the proximity of HSB, IC, and the disposal area would be impacted by dredging associated with this alternative. In addition, the out-of-basin diversion route affects the largest number of known sites, as well as the greatest number of sites potentially eligible for the National Register.

4.9.4 Alternative D: Out-of-Basin Diversion and Containment of Contaminated Sediments

HSB would be diverted from 3 miles upstream of the highly contaminated area directly to the Tennessee River. Channel sediments between HSB Mile 2.4 and IC Mile 0.0 would be hydraulically dredged. A containment dike as illustrated in Figure 9 would be constructed. Channel and critical overbank sediments within the containment area would be covered with compacted clay and clean fill. Non-critical overbank sediments may or may not be covered.

Implementation Summary--

1) Conduct cultural resources survey of impacted areas and implement necessary actions to recover or preserve valuable sites.

2) Construct out-of-basin diversion of HSB and McDonald Creek cut-off channel.

3) Raise Patton Road to elevation 578 and construct dike northwest of Patton Road. This dike combination will serve as a diversion dike for HSB and will help contain contaminated sediments in HSB.

4) Construct western containment dike, drainage channel and pumping station as shown in Figure 10.

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Table 9. Cost Summary for Alternative C (As Detailed in Table III-14)

Dredging Method(s) Utilized	Total Estimated Cost (Millions of Dollars)
All Hydraulic Dredging	122.25
Dragline Dredging between HSB Miles 2.4 and 5.6, Remainder Hydraulically Dredged	127.40

Estimated Effect of Other Options on Cost Estimate (Millions of Dollars):

-Implement Noncritical Overbank Removal Option in Reach A	+ 14.57
-Delete Carbon Adsorption From Return Water Treatment System	- 4.16
-Implement Mine Disposal	+ 15.04
(Including Disposal of Overbank Sediments)	+ 43.37
-Delete Hydraulic Dredging of Reach C	- 17.94
-Delete Hydraulic Dredging of Reaches B and C	- 26.93
-Use Alternate Sector Routings to Keep Diversion within RSA Boundaries (i.e., Sectors A-2, B, C-2, D-2, and E)	+ 8.22*

*Cost increase is attributed almost entirely to the increased amount of bedrock expected to be encountered during excavation of the channel.

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5) Clear and grub critical overbank area. Remove snags and debris from HSB channel.

6) Cover critical overbank and channel sediments within the containment area with a minimum of 6 inches of compacted clay and 18 inches of soil suitable for supporting vegetative cover.

7) Establish vegetative cover on placed fill.

8) Dredge contaminated channel sediments downstream from HSB Mile 2.4 as summarized in items (1) through (11) of Section 4.9.2

9) Implement areawide environmental monitoring and long-term monitoring and maintenance of the permanent disposal site.

Options Available With Alternative D--

1) Apply cover to entire overbank area within containment.

2) Delete carbon adsorption from return water treatment system.

3) Remove dewatered dredged sediments from TDMDA and dispose of in an abandoned mine.

4) Delete hydraulic dredging of Reach C (IC).

5) Delete hydraulic dredging of Reaches B and C (HSB Mile 2.4 to IC Mile 0.0).

6) Use alternate alignment for out-of-basin diversion to maintain it within RSA boundaries.

Cost Summary--The cost summary for Alternative D is in Table 9.

Impact Summary for Alternative D--The environmental impacts of out-of-basin diversion and of containment have been discussed in Sections 4.4.5 and 4.6.4.

With regard to Cultural Resources, Alternative D impacts a large number of high probability locations. All probable or potential sites in the proximity of HSB, IC, and the disposal area would be impacted by dredging or covering associated with this alternative. In addition, the out-of-basin diversion route affects the largest number of known sites as well as the greatest number of sites potentially eligible for the National Register. Construction of the dewatering dike north of HSB may impact additional sites in a high probability area.

4.9.5 Alternative E. Within-Basin Diversion and Removal of Contaminated Sediments

HSB would be diverted around the highly contaminated channel between Miles 3.9 and 5.6. A containment dike as illustrated in Figure 8 would

Table 16. Cost Summary for Alternative D (As Detailed in Table III-17)

Areal Extent of Cover Application Within Containment	Total Estimated Cost (Millions of Dollars)
Channel and Critical Overbank Only	122.89
Channel and Entire Overbank	129.77

Estimated Effect of Other Options on Cost Estimate (Millions of Dollars):

-Delete Carbon Adsorption From Return Water Treatment System	- 4.16
-Implement Mine Disposal	+ 12.40
-Delete Hydraulic Dredging of Reach C	- 29.02
-Delete Hydraulic Dredging of Reaches B and C	- 40.63
-Use Alternate Sector Routings to Keep Diversion Within RSA Boundaries	+ 8.22

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be constructed. HSB and IC channel sediments downstream from the containment area would be hydraulically dredged. Channel sediments within the containment area may be hydraulically dredged under near-zero flow conditions, or dragline dredged if the containment area is dewatered. Critical overbank sediments would be dragline dredged, and non-critical overbank sediments may or may not be dredged.

Implementation Summary.

1) Conduct cultural resources survey of impacted areas and implement necessary actions to recover or preserve valuable sites.

2) Construct within-basin diversion and diversion/containment dike.

3) Construct TDMDA.

4) Secure lease on return water treatment system and set up at TDMDA.

5) Clear and grub critical overbank area, dredge those sediments with a dragline to a depth of 3 feet, and dispose of in TDMDA.

6) Dredge HSB and IC channels by one of the two following methods:
a) Hydraulic dredging as summarized in items (5) through (9) of Section 4.9.2.
b) Dragline dredge HSB channel sediments within the containment area (HSB Miles 4.0 to 5.6) to a depth of 3 feet. Dispose of sediments in the TDMDA. Dredge sediments downstream from HSB Mile 4.0 hydraulically as summarized in items (5) through (9) of Section 4.9.2.

7) Dewater dredged material in TDMDA.

8) Permanently dispose of DDTR-contaminated sediments by closing TDMDA as a landfill.

9) Implement areawide environmental monitoring and long-term monitoring and maintenance of the permanent disposal site.

Options Available With Alternative E--

1) Remove non-critical overbank sediments to a depth of 3 feet.

2) Delete carbon adsorption from return water treatment system.

3) Remove dewatered sediments from TDMDA and dispose of in an abandoned mine.

4) Delete dredging of Reach C (IC).

5) Delete dredging of Reaches B and C (HSB Mile 2.4 to IC Mile 0.0).

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Cost Summary--The cost summary for Alternative E is in Table 10.

Impact Summary for Alternative E--The environmental impacts of within-basin diversion and of dredging and disposal have been discussed in Sections 4.5.5 and 4.3.6.

With regard to Cultural Resources, all probable or potential sites in the proximity of HSB, IC, and the disposal area would be impacted by dredging associated with Alternative E. In addition, the within-basin diversion channel and dikes will impact one reported site and possibly other potential sites.

4.9.6 Alternative F: Within-Basin Diversion and Containment of Contaminated Sediments

HSB would be diverted around the highly contaminated channel between Miles 3.9 and 5.6. A containment dike as illustrated in Figure 8 would be constructed. HSB and IC channel sediments downstream from the containment area would be hydraulically dredged. Channel and critical overbank sediments within the containment area would be covered with compacted clay and clean fill. Non-critical overbank sediments may or may not be covered. An option is given to construct a disposal area within the diversion/containment dike for sediments dredged downstream from HSB Mile 3.9.

Implementation Summary--

1) Conduct Cultural resources survey of impacted areas and implement necessary actions to recover or preserve valuable sites.

2) Construct within-basin diversion and diversion/containment dike.

3) Clear and grub critical overbank area. Remove snags and debris from the HSB channel.

4) Cover critical overbank and channel sediments within the containment area with a minimum of 6 inches of compacted clay and 18 inches of soil suitable for supporting vegetative cover.

5) Establish vegetative cover on placed fill.

6) Dredge contaminated sediments downstream from HSB Mile 2.4 as summarized in items (1) through (11) of Section 4.9.2.

7) Implement areawide environmental monitoring and long-term monitoring and maintenance of the permanent disposal site.

Options Available With Alternative F--

1) Use within-basin diversion containment area for disposal of dredged material.

Table 11. Cost Summary for Alternative E (As Detailed in Table III-20)

Dredging Method(s) Utilized	Total Estimated Cost (Millions of Dollars)
All Hydraulic Dredging	90.67
Dragline Dredging Between HSB Miles 2.4 and 5.6, Remainder Hydraulically Dredged	91.43

Estimated Effect of Other Options on Cost Estimate (Millions of Dollars):

-Implement Noncritical Overbank Removal Option in Reach A	+ 14.57
-Delete Carbon Adsorption From Return Water Treatment System	- 4.16
-Implement Mine Disposal	+ 16.51
(Including Disposal of Overbank Sediments)	+ 43.37
-Delete Hydraulic Dredging of Reach C	- 29.02
-Delete Hydraulic Dredging of Reaches B and C	- 40.63

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2) Cover non-critical overbank sediments

3) Delete carbon adsorption from return water treatment system

4) Remove dewatered sediments from TDMDA and dispose of in an abandoned mine

5) Delete dredging of Reach C (IC)

6) Delete dredging of Reaches B and C (HSB Mile 2.4 to IC Mile 0.0)

Cost Summary--The cost summary for Alternative F is in Table 11.

Impact Summary for Alternative F--The environmental impacts of within-basin diversion and of containment have been discussed in Sections 4.5.5 and 4.6.4.

With regard to Cultural Resources, all probable or potential sites in the proximity of HSB, IC, and the disposal area would be impacted by dredging or covering associated with Alternative F. In addition, the within-basin diversion channel and dikes will impact one reported site and possibly other potential sites.

5.0 PREDICTED EFFECTIVENESS OF MITIGATION ALTERNATIVES

There are several measures by which the effectiveness of a mitigation alternative can be estimated. These include the following:

1) Percent or mass of contamination contained in-place
2) Percent or mass of contamination removed and disposed of
3) Residual contamination left in the system and the potential for its mitigation by natural processes
4) Degree of short-term transport of DDTR downstream during implementation
5) The time required for DDTR levels in biota (particularly fish) to reach acceptably low levels.

The distinction is made between items 1) and 2) because there is an inherent difference in effectiveness between the two. Covering contaminated sediments in place can be assumed to be near 100 percent effective, provided proper long-term maintenance is implemented. Removing and disposing of contaminated sediments is subject to the following shortcomings which preclude its being 100 percent effective:

- Some degree of residual contamination will inevitably be left behind

- Short-term transport of DDTR to the TR will occur to an undetermined extent during dredging

- The potential for leakage or spillage during remov operations.

Table 12. Cost Summary for Alternative F (As Detailed in Table III-23)

Disposal Option Implemented	Total Estimated Cost (Millions of Dollars)
Use TDMDA	
-excluding overbank covering option	88.32
-including overbank covering option	94.36
Use Within-Basin Diversion Containment Area for Disposal Area	88.36

Estimated Effect of Other Options on Cost Estimate (Millions of Dollars):

-Delete Carbon Adsorption From Return Water Treatment System	- 4.16
-Implement Mine Disposal	+ 14.00
-Delete Hydraulic Dredging of Reach C	- 29.02
-Delete Hydraulic Dredging of Reaches B and C	- 40.63
-Obtain On-Site Borrow Material for Construction and Closure of Disposal Site Within the Containment Area (Suitability must be determined)	- 5.09

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The degree to which these occur can be minimized by careful monitoring and control of the dredging operation. However, since they will inevitably occur to some extent, dredging and removal can be assumed somewhat less effective than in-place containment.

The effectiveness of any of the alternatives is affected by residual contamination which can result from (1) areas of contamination where no direct mitigation is attempted and (2) contamination remaining due to inefficiency in the mitigation technique applied. Obviously if a decision is made not to dredge the lower reaches of IC, the contamination left in this area will reduce the effectiveness of the alternative.

Item 4 pertains strictly to dredging. The degree to which downstream DDTR transport occurs depends on the alternative selected as well as turbidity control at the dredge head. A within-basin diversion will eliminate DDTR transport from the highly contaminated area within the containment dike, but will afford no protection outside the dike. The out-of-basin diversion can eliminate DDTR transport from areas upstream of Dodd Road as well as greatly reduce it below Dodd Road and in IC.

A comparison of effectiveness of alternatives (excluding any consideration of biota contamination) is given in Table II-54.

Finally, a key factor is the effectiveness of an alternative in reducing DDTR levels in fish to below the 5 ppm FDA guideline. Unfortunately, this is probably the most difficult measure of effectiveness to predict with accuracy. On the one hand one can state that removal or isolation of a high percentage of the DDTR in the HSB-IC system can, in the long term, only help the situation. Yet because of the high potential for significant fish contamination from even low residual levels of DDTR, one cannot easily predict how quickly positive results can be realized following a clean-up effort.

Several factors should be considered in attempting to judge how long it might take for DDTR levels in fish to be reduced to below 5 ppm. These include current contamination levels, method of contamination, degradation of DDTR by natural processes, effectiveness of DDTR removal, and rate at which fish can excrete or break down DDTR. In Appendix II, Section 5.3, these factors are considered in some depth. Channel catfish in Wheeler Reservoir downstream of IC appear to have DDTR concentrations on the order of 10 ppm due to very low level contamination of either or both sediment and water. Near IC DDTR levels in channel catfish are higher which may be due to higher localized sediment or water DDTR concentrations and/or to migration of fish in and out of IC. Nevertheless, it appears that for channel catfish bioconcentration of DDTR produces fish concentrations in excess of 5 ppm from extremely low environmental concentrations. Hence, it is not reasonable to expect channel catfish DDTR levels to drop below 5 ppm until environmental DDTR levels are reduced below what currently exists in the TR. Presently this level is below what might reasonably be expected to initially remain in IC and HSB after a mitigation alternative was completed. Further, these levels of DDTR in the TR water and sediment would still be present even if a mitigation alternative were completed. Following the completion of

Table 13. Predicted Effectiveness of Mitigation Alternatives[1]

Alternatives	Estimated % DDTR[2] Removed	Estimated % DDTR[2] Contained In-Place	Estimated % DDTR[2] Total	Residual Contamination Remaining	Potential for Short-Term Transport During Implementation
A	0	0	0	100%	None
B	99.4	0	99.4	0.6% not isolated plus residual contamination left in all dredging areas	Potential exists during dredging of all areas
C	99.4	0	99.4	0.6% not isolated plus residual contamination left in all dredging areas. All residual contamination subject to low flow and increased sedimentation	Potential reduced or eliminated in Reach A, greatly reduced in Reach B, and reduced in Reach C.
D	1:9	97.5	99.4	0.6% not isolated plus residual contamination left in Reaches B and C. All residual contamination subject to low flow and increased sedimentation.	Potential eliminated in Reach A, greatly reduced in Reach B, and reduced in Reach C.
E	99.4	0	99.4	0.6% not isolated plus residual contamination left in all dredging areas. Residual contamination within diversion dike isolated from HSB flow.	Potential eliminated within containment dike; potential exists during dredging of all other areas.
F	13.2	86.2	99.4	0.6% not isolated plus residual contamination downstream from HSB Mile 3.9. Ponded area within diversion dike isolated from HSB flow.	Potential eliminated within containment dike; potential exists during dredging of all other areas.

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Table 13. Predicted Effectiveness of Mitigation Alternatives (Continued, Page 2)

Alternatives	Estimated % UDTR[2] Removed	Contained In-Place	Total	Residual Contamination Remaining	Potential for Short-Term Transport During Implementation
F[3]	13.2	86.5	99.7[4]	0.3% not isolated plus residual contamination downstream from HSB Mile 3.9.	Potential eliminated within containment dike; potential exists during dredging of all other areas.

[1] Estimates for action alternatives assume mitigation of contamination, in the noncritical overbank.

[2] Percentage of estimated total, 838 tons.

[3] Using diversion containment area for disposal of dredged material.

[4] Ponded area within containment filled and covered, isolating an additional 0.4%.

any of the alternatives except natural restoration, it is assumed that the flow of DDTR to the TR would be significantly reduced. With little or no "fresh" DDTR entering the river, it could be expected that existing concentrations would go down.

Unfortunately, no data exists regarding natural degradation rates for DDTR under conditions similar to those found in IC and TR. Data for breakdown rates in soils show figures ranging from less than one year to greater than 30 years depending on a number of conditions. Under the assumption that some mitigation action had essentially eliminated the movement of DDTR from IC to the TR and that natural breakdown in an aquatic environment might roughly parallel breakdown in the soil, significant reductions in DDTR might occur in roughly 1-30 years.

Since the uptake and reduction of DDTR in fish has been shown to occur in significantly shorter time spans than appear to be required for natural degradation of DDTR, it is assumed that the fish are at or near equilibrium with respect to DDTR in the environment. Consequently, one would expect DDTR levels in fish to closely parallel reductions of DDTR in the environment.

If the assumptions and conditions noted above are valid, it might take from a relatively few to 30 or more years for DDTR levels in channel catfish in the TR to drop below the 5 ppm guideline following completion of one of the action alternatives. Further, since any of the action alternatives will leave at least some residual amounts of DDTR in IC above what currently exists in the TR, the channel catfish in IC can be expected to remain contaminated for even longer periods of time.

No difference between the action alternatives can be detailed regarding how quickly DDTR levels in channel catfish in IC and HSB can be reduced.

The natural restoration alternative is predicted to be ineffective in controlling DDTR contamination of the HSB-IC-TR system.

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